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WOODS HOLE OCEANOGRAPHIC INSTITUTION

WOODS HOLE, MASSACHUSETTS

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WOODS HOLE OCEANOGRAPHIC INSTITUTION

Woods Hole, Massachusetts

UR 6579

Reference No. 52-47

NORTH ATLANTIC OCEANOGRAPHY

under Task Order I

conducted during the period

January 1, 1952 - March 31, 1952

Periodic Status Report No. 23
Submitted to Geophysics Branch, Office of Naval Research
Under Contract N6onr-27701 (NR-083-004)

June 1952

APPROVED FOR DISTRIBUTION ______________________
Director

[redacted]

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According to the terms of Contract N6onr-27701 (NR-083-004), the work to be performed by the Contractor shall consist of the following:

1. The Contractor shall furnish the necessary personnel and facilities for and, in accordance with any instructions issued by the Scientific Officer or his authorized representative, shall

(a) conduct research, analyze, and compile data and technical information, prepare material for charts, manuals, and reports, and foster the training of military and civilian personnel in the following fields of oceanography:

(i) permanent currents;
(ii) interaction of the sea and atmosphere (including wind waves, swell, and surf);
(iii) the distribution of physical properties;
(iv) the distribution of chemical properties;
(v) the distribution of organisms;
(vi) the characteristics of the sea bottom and beaches;
(vii) tides, tidal currents, and destructive sea waves; and
(viii) the physics and distribution of sea and terrigenous ice.

The research shall include, but not necessarily be limited to, the following:

(1) studies of North Atlantic oceanography;
(2) wave observations and analysis;
(3) current measurements;
(4) studies of Arctic oceanography;
(5) development of unattended instruments;
(6) thermocline studies; and
(7) studies on inshore oceanography.

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INTRODUCTION

During the winter quarter here reported on, the major effort was made at sea. The question how best to employ ATLANTIS and ALBATROSS III during the winter months had received careful consideration and the general plan of the courses to be followed was given in Figure 2 of the previous progress report (WHOI Ref. No. 52-11). That the tactics of this cruise turned out to be wise was perhaps due as much to good luck as to good management. However, it may be instructive to review here, in the light of retrospect, the various basic considerations.

In preparing sonar charts we have always been handicapped by the almost complete lack of bathythermograph observations from the trade wind latitudes of the North Atlantic. To fill this need was a major objective of the expedition and it is hoped that we can obtain a corresponding series of observations from the same area during the coming summer.

From the standpoint of long range sound transmission, the trade wind area was also very deficient in deep temperature and salinity observations. Thus, a major objective of the cruise was to provide basic data over a wide area in support of acoustical research and development. In addition, the ATLANTIS dropped a long series of charges for the Bermuda Sofar Station.

After the vessels put in at Trinidad on April 15, emphasis was shifted from ordinary oceanography to geophysics. Therefore, the first 3-1/2 month period of the 5 month cruise can be considered to have been a joint BuShips-ONR expedition, while the last 1-1/2 month period was spent more strictly in support of ONR projects through the group from the Lamont Geological Observatory. All but four of the Woods Hole scientific party left the vessels at Trinidad.

Although the area of operations and the basic plan of the cruise were largely governed by acoustical needs, there was no real conflict with the strictly oceanographic objectives reported on here. In fact, as things turned out, it would have been most unwise in the trade wind belt to place full reliance in the techniques that have been so successful in the case of the Gulf Stream during recent years. To have attempted to track the surface current patterns with the bathythermograph and GEK would have led to most confusing results, for the swift surface currents were not well marked thermally, nor were they located where we thought they would be.

Instead, the main emphasis was devoted to chemical observations which will undoubtedly yield most useful information on the slower deep circulation pattern on which the narrow swift

surface currents were superimposed. When combined with the previous chemical work of the METEOR and the ATLANTIS, a very satisfactory analysis of the general circulation over the whole northeast trade wind area should now be possible. Future expeditions can perhaps deal successfully with more limited parts of the shallow, swift streaks of flow.

A secondary objective of the recent expedition was to gain firsthand evidence of the deficiencies of the weather maps in low latitudes over the ocean. How streaky are the winds? How well are they described by the scattered daily observations available from low latitudes?

Both vessels carried recording echo sounders and these, of course, added greatly to the daily routine scientific intake. Some of the programs carried out during the cruise are discussed in more detail below, but many months must pass before the extensive data can be fully digested.

In the laboratory theoretical and experimental studies were continued, as well as the more routine aspects of the program. These, too, are reported in more or less detail below.

Perhaps the chief gains of the winter for the future were the following. The theoretical studies of Dr. Malkus and Mr. Stern had shown that it should be possible to record continuously the transport through the Florida Straits by measuring the electrical potential between electrodes on either side of the current. Permission has been received to use an extra telephone circuit between Key West and Miami for this purpose. It is hoped that the necessary equipment can be installed early in the summer. For some time, under a Bureau of Ordnance contract, we have been studying surface effects as seen by infrared devices. Through this experience, we have come to hope that a practical, air-borne surface "temperature" recorder could be developed. During March, Mr. Parsons conceived the basic design of such an instrument and began its construction. If no unforeseen difficulties develop, this should prove to be a powerful new tool in Gulf Stream studies and also may well greatly advance marine meteorology.

STUDIES OF NORTH ATLANTIC OCEANOGRAPHY

Trade Wind Cruise

Chemical and Biological Investigations. During the period 15 January to 15 April, the ATLANTIS and the U. S. Fish and Wildlife vessel ALBATROSS III were engaged in an investigation of the currents and of the chemistry and biology of the equatorial

region. In brief, the objectives of the chemical and biological investigations were to determine the characteristics of the water related to the upwelling which occurs off the north African coast and to trace this nutrient-enriched water as far as possible as it spreads over the Atlantic. Periodic zooplankton tows were taken to determine the distribution of the plankton in the upwelled water and in surrounding regions. Water samples for phytoplankton were preserved for future study.

More than 200 hydrographic stations were occupied by the two ships. In addition to the salinity and temperature observations, analyses for dissolved oxygen were made on each sample and a portion of the water was reserved for ultimate analysis for total nitrogen and total phosphorus. At almost half of the stations, analyses were made on shipboard for inorganic phosphorus, nitrate and nitrite nitrogen and dissolved silicates, and filtrations to isolate the particulate phosphorus were completed.

It will take about a year to complete the analysis of the samples for total nitrogen and phosphorus and for particulate phosphorus, There are nearly 6,000 of these samples to be analyzed.

The vertical distributions of temperature, oxygen, inorganic oxygen, and nitrate nitrogen at seven of the stations are shown in Figures 1 and 2. The locations of these stations are given in Table I. The three stations in Figure 1 lie on a north-south line extending from 30° north to 5° south latitude. The four stations illustrated in Figure 2 lie on an east-west line extending from 23° to 54° west latitude.

The results obtained with the dissolved oxygen are related to the variations in the other nutrient elements and will be discussed briefly. The oxygen minimum, which is related to the quantity of organic material decomposed, was found at 700 meters or more in the northern part of the area. The dissolved oxygen at this depth was found to be 3 ml./L. or more. Appreciably lower values were found within a broad tongue extending from below the equator to about 25°N. latitude. The lowest concentration observed was 0.5 ml./L. about 600 miles off the coast of Africa at 15° N. latitude, 30°W. longitude. The band of unusually low values extended as far west as 49°. A chart showing the distribution is given in Figure 3 which also indicates the locations of the stations occupied.

Double minima of oxygen concentration were found off the African coast just north and south of Dakar and these double minima were generally found in a band nearly 500 miles wide extending in a southwesterly direction from Dakar as far west as 37°W. longitude. The two minima were generally separated by

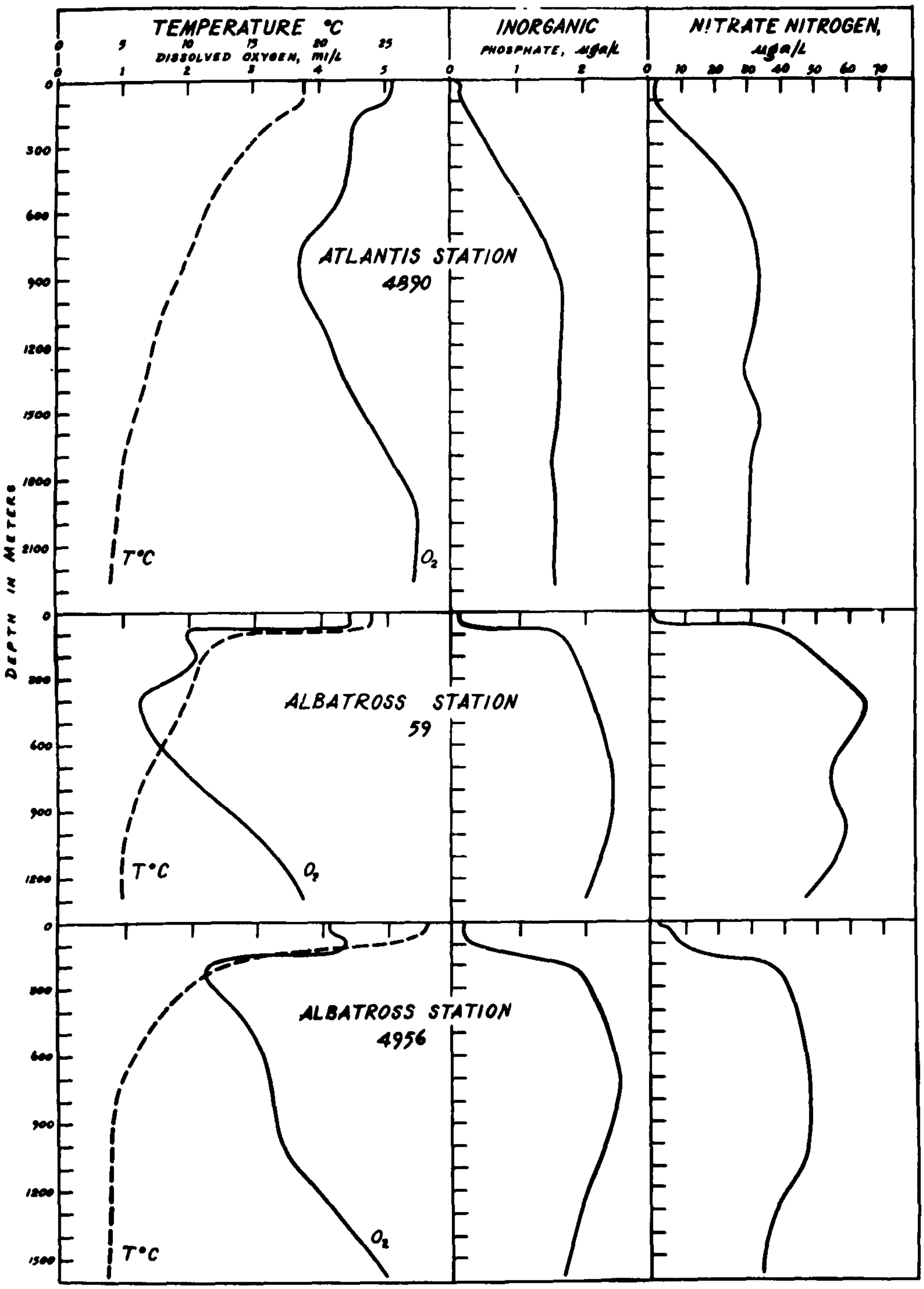
TEMPERATURE °C
0 5 10 15 20 25
DISSOLVED OXYGEN, ml/L
0 1 2 3 4 5
INORGANIC
PHOSPHATE, μga/L
0 1 2
NITRATE NITROGEN,
μga/L
0 10 20 30 40 50 60 70
DEPTH IN METERS
ATLANTIS STATION
4890
ALBATROSS STATION
59
ALBATROSS STATION
4956
T°C
O_2

FIG. I

RESTRICTED

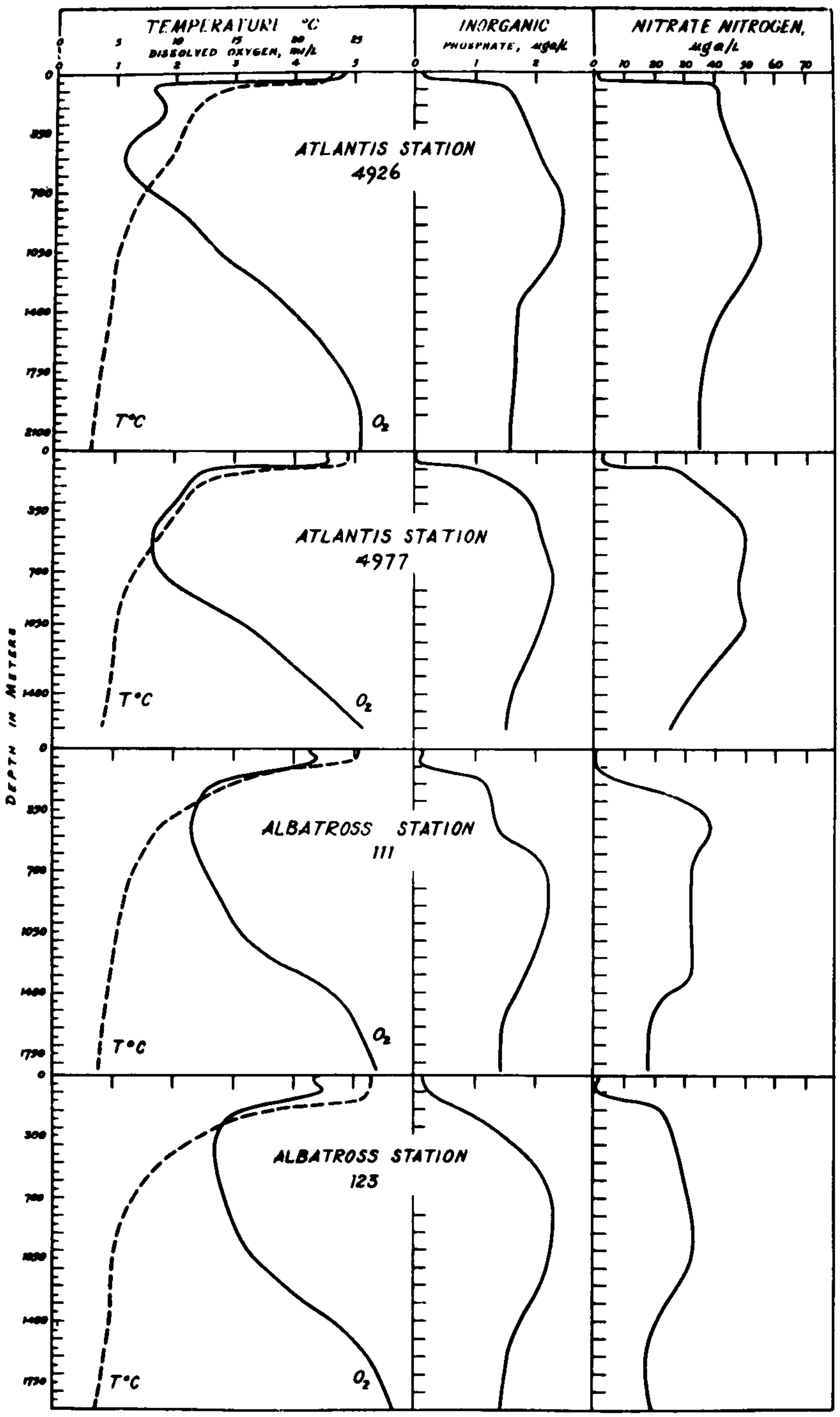

FIG. 2

RESTRICTED

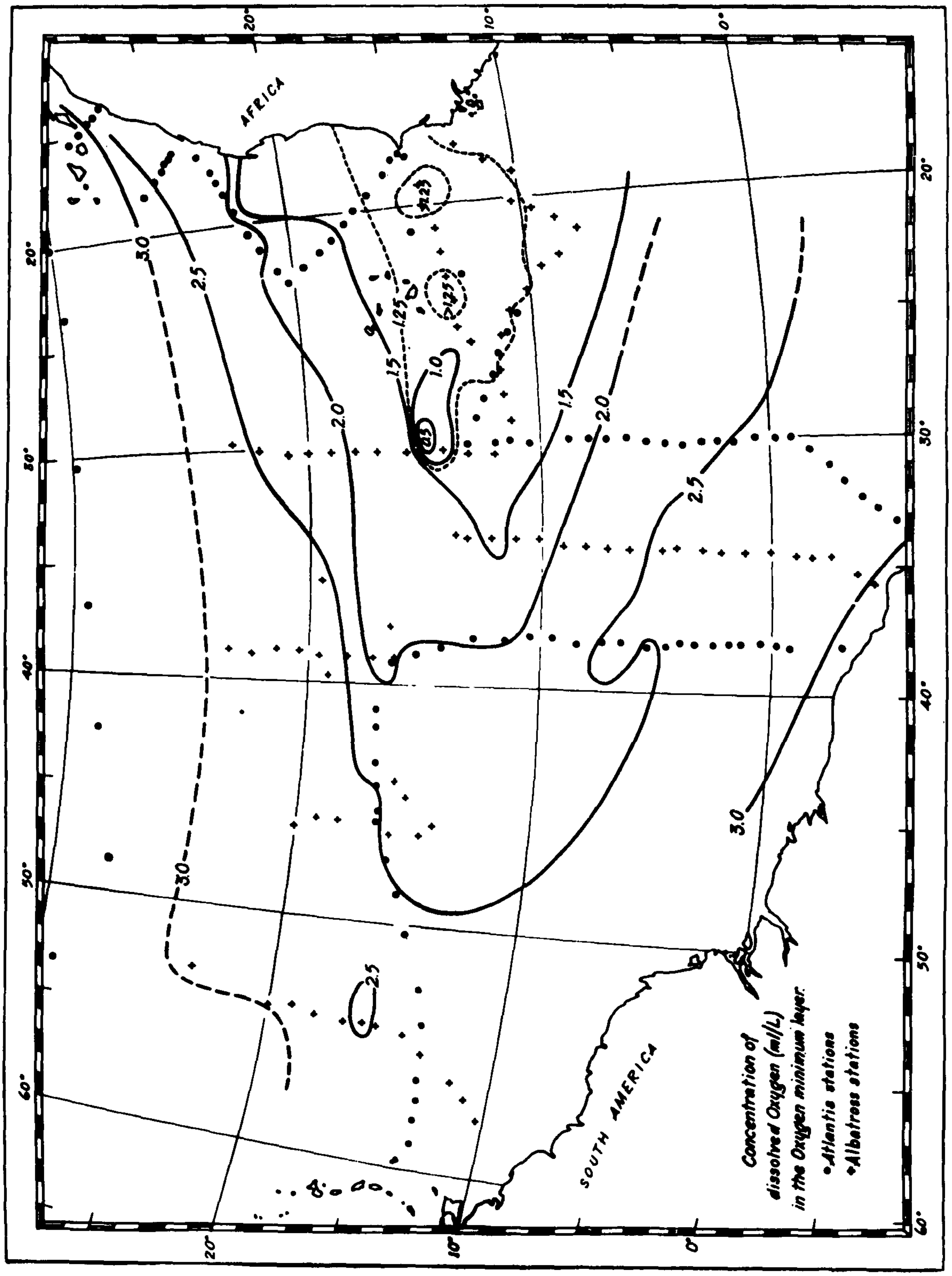
AFRICA
SOUTH AMERICA
Concentration of dissolved Oxygen (ml/L) in the Oxygen minimum layer.
•Atlantis stations
+Albatross stations

FIG.3

TABLE I

Locations of the stations where the data given in Figures 1 and 2 were obtained

Vessel	Station No.	Latitude	Longitude
ATLANTIS	4890	29°47'N	23°16'W
"	4926	12°53'	22°59'
"	4956	05°37'	33°16'-33°20.5'
"	4977	13°01'	37°56'
ALBATROSS III	59	12°01'	30°12'
"	111	14°04.5'	45°58'
"	123	14°00'	54°23' to 25'

a depth of about 200 meters, the deepest one being found at 400 to 600 meters.

Associated with these low values for the oxygen concentration were unusually high values for inorganic phosphate and nitrate nitrogen. Thus, in the north part of the area, values for inorganic phosphorus rarely exceeded 1.7 μgA./L. and nitrate nitrogen rarely exceeded 35 μgA./L. In the region where low values were found in the oxygen minimum, the phosphate concentration was frequently greater than 2.5 μgA./L. and nitrate nitrogen concentration frequently exceeded 50 μgA./L. The phosphate concentrations are comparable to those previously reported from this region. Many of our nitrate nitrogen values are greater than any previously recorded. As a result, the ratio of nitrogen to phosphorus throughout the parts of the ocean where the influence of the upwelling along the African coast can be identified is about 20 atoms to 1. This ratio, throughout most of the North Atlantic Ocean, is closer to 15 atoms to 1. Further analysis of the data will be necessary before the extent of this effect is known.

Although the plankton tows have not been worked up quantitatively, the variation in quantity was quite pronounced. Along the north African coast it was not at all uncommon to obtain two quarts of material in 1/2 hour surface tow made at night with a 3/4 meter net. This dense plankton extended about 300 miles offshore. Further from the coast most of the tows, taken under comparable conditions, contained no more than a pint and sometimes as little as a quarter of a pint of plankton. There was also a marked variation in the species involved.

Meteorology. The trade wind cruise also provided a good opportunity for the collection of meteorological observations.

The following meteorological elements were observed:

At Hydrographic stations: weather, wind, sea, swell, wet bulb, dry bulb;

At Bathythermograph lowerings: weather, wind, clouds, sea, bucket temperatures, wet bulb, dry bulb;

(The psychrometer was read every two hours).

There were about 200 hydrographic stations and about 3,200 BT lowerings. In addition to these, regular six-hourly ships surface weather observations were made by the ships' officers and transmitted by radio to the appropriate shore station in Code FM 21.

On an ATLANTIS cruise to the same area in 1932, a very abrupt line of demarcation was noticed between the light and variable winds of the Horse Latitudes and the easterlies of the Trades. The track of the ALBATROSS III in the trade wind cruise crossed the 20th parallel nine times between longitudes 30° and 54° without any such line of demarcation being found. It is notable, however, that there was no well developed Bermuda-Azores high during the periods when the crossings were made. On all crossings there were NE trades of force two or more to the south of the 19th parallel. To the north of that parallel were encountered:

1. A gradual shift to northerly winds (on four crossings);

2. Continued NE trades to the northern limit of the ships' track (on four crossings); or

3. Variable winds from ENE to SE (on one crossing which was near a frontal area).

The wind data from these nine crossings fit in well with the curves of "Northern limit of the Northeast Trades" and "Sailing route by way of the Trades" shown on the H.O. Pilot Charts No. 1400 for February, March, and April.

The area of northeast trades extended from about 20°N to about 3°N. The range of force was Beaufort 1 to 6 with a strong predominance of forces 3 and 4. Southeast trades of force 2 to 4 were encountered between about 4°S and Recife, Brazil.

On the ALBATROSS' southbound crossing of the equator along 34°W in early March, the wind was generally NE force 2 from 5°N to 3°N, becoming generally force 1 with a range of 0 to 3 between 3°N and 4°S and becoming SE trades at 4°S. There were widely scattered showers south of 2°N.

When the ALBATROSS returned across the equator, along 38°W in late March, there was no doldrum belt but merely a transition zone of variable easterly winds of force 2 to 5 between 1°S and 2°N. There were frequent showers and some steady rain during the crossing. Between 3°N and 4°15'N there was moderate to heavy rain and the wind rose from force 4 to 6. The rain ceased near 4°15'N and as the ship continued northward the wind decreased but slowly, reaching force 4 some 26 hours later north of 7°N.

Synoptic weather maps for March were later consulted at the British Air Ministry station at Piarco Airport, Trinidad.

These maps show that while the intertropical front lay dormant along the equator during the former crossing, its activity intensified and the front itself moved northward during the latter crossing. It is much to their credit that the British forecasters had been able to analyze their maps so well over the water without benefit of ships' weather observations in the immediate area.

Drift Station. The ATLANTIS occupied a drift station from 1332 on the 31st of March to 1456 on the 3rd of April. During this period the ship followed a buoy which drifted with the surface layer (to a depth of 5-1/2 meters). On the third day, a second buoy, with a drag at a depth of 50 meters, was set adrift. The deep and the shallow buoys were followed for 17 hours and were found to drift at approximately the same speed but diverged at an angle of 18° with the deeper buoy moving to the right of the shallower one.

During the time the station was occupied, the wind was generally SE force 3. The wind direction varied between 105° and 150° and the force fluctuated from force 1 to 4 Beaufort. The shallow (5-1/2 meter) buoy drifted toward the north, 356°, at an average rate of .73 knots, in spite of the fact that every effort had been made to place the buoys at what was considered the axis of the northern Equatorial Current.

Above the water line, the buoys consisted of a 3 meter bamboopole with 2 flash light bulbs at the top and a small brightly colored flag centered one meter from the top. The light bulbs were connected by wire to 8 dry cell batteries in a waterproof bag beneath the water line. Below the surface, the shallow buoy consisted of 3 life jackets, 4 plywood fins totaling 180 cm. in depth, a canvas covered ring 130 cm. in diameter, and 5 sash weights. The deeper drag consisted simply of the life jackets, a 2.5 meter long 2 x 4, 50 meters of steel wire, a cross made of bamboo covered with a 2 square meter canvas, and at the bottom the 5 sash weights.

At the water line, 4 cans of dye marker were attached to each buoy. No measureable drift of the dye away from the buoys was apparent.

Current Measurements by G.E.K. One G.E.K. was operated throughout the Recife-Trinidad phase of the trade wind cruise covering the waters south of the Sargasso Sea and north of the northern coast of South America from 34°W longitude to the Antilles. In addition to the mass of data on currents gathered in this region, this cruise permitted the G.E.K. to be operated on and near the magnetic equator. As a further study of the latter kind, a run due north along 38°W longitude was made from

-4°S to 21°N on which navigational, G.E.K., and dynamic sections were made nearly simultaneously. It is hoped that the results of this section may permit an estimate of the reliability of the latter two methods in low latitudes where both methods approach their limits of usefulness, but for different reasons. Navigation was entirely astronomical. Through the courtesy of Captain Mysona every sight was taken by three observers working simultaneously but independently, so that the average position is likely to be far less in error than other experimental quantities which must be taken into account.

STUDIES OF ARCTIC OCEANOGRAPHY

Arctic Field Observations. The 1952 winter cruise to the Arctic by the USS EDISTO (AGB-2) and USS ATKA (AGB-3) commenced on the seventh of January. Mr. Metcalf was one of a team of five civilian oceanographers and ice observers on the EDISTO. The rest of the group of that ship as well as the five oceanographers on the ATKA were from the Hydrographic Office.

Most of the month of January was spent on logistic operations, but on the 28th of January the two ships commenced the oceanographic program off the southeast coast of Greenland. In spite of frequent strong winds, both ships were able to proceed on schedule with the work which consisted of standard hydrographic stations at which the temperature, salinity, and oxygen content of the water were studied along with periodic bathythermograph lowerings and ice observations.

Unfortunately, the EDISTO suffered a broken propeller blade in the East Greenland ice pack and was forced to abandon the rest of its program after the fifteenth hydrographic station. The ATKA continued its work and returned to Boston at the end of February having occupied fifty-three hydrographic stations.

At the end of the quarter, the salinity samples had not yet been titrated, but it is felt that the cruises of the two ships, especially that of the ATKA, will greatly increase our understanding of this interesting region east of Greenland at a season when the data have in the past been extremely few and far between.

The ice observations from Belle Isle north along the Labrador Coast to about 55°N showed the ice limits to be slightly inshore of the average position as given in the "Ice Atlas of the Northern Hemisphere" for January. During the period the EDISTO was in this area, great enough changes were continually taking place in the position of the ice limits to

suggest that the apparent departure from the "average" could not necessarily be taken as significant.

Again on the east side of Greenland in the Denmark Strait region, the offshore limits of the pack ice were not as far from the coast as the "Ice Atlas" shows the average limits. However, it is felt that the ice was not under observation for a long enough period for a final statement on the subject to be made.

It is tentatively suggested that the ice in both the Labrador and the East Greenland currents was on the light side of average during January and early February.

A second airborne expedition to the Arctic Ocean, Operation SKIJUMP II, was made this winter. This time three Naval aircraft participated; 2 P2Y Neptunes and the same R4D as was used last year. The P2Y's were able to fuel the R4D out at sea, greatly increasing her range.

Many improvements in technique were made this year, chief among them being the use of a gasoline-driven ice-auger which was found capable of boring a 12" diameter hole through five feet of ice in about ten minutes. The 12" hole was found ample for the raising and lowering of Nansen bottles. A tent was rigged over the hole on each station and a plentiful supply of hot air from a heater insured that no freezing of samples took place.

On 27 March the port landing gear of the R4D collapsed on take-off; she lost the port propeller and had to be abandoned in 82°22'N, 145°20'W, the site of the last hydrographic station.

A total of five stations were made to depths of 3000, 2000, 600, 2300, and 2100 meters. It was unfortunate that the work had to be abandoned so early in the season, as April is the best month for light, weather and ice conditions for airplane operations.

<u>Relations between North Atlantic Ice and Arctic Weather</u>.

A. Longer period variations in the ice of the North Atlantic-Arctic and in the precipitation.

In an attempt to extend further (Schell, WHOI Ref. No. 50-53) the general agreement between the longer period variations in the ice and the precipitation in the Atlantic-Arctic and adjacent regions, first the average ten-yearly ice limits in the area between 50°W and 70°E were constructed from the monthly ice charts published each year by the Danish Meteorological Institute. Only the results covering the three decades:

1901-1910, 1911-1920, 1921-1930 and the nine-year period 1931-1939 could be considered. Next the average latitude of the ice limit was obtained from the values of the limits at each 5° meridian within the area considered. The figures derived were then compared with the average ten-yearly values of the annual precipitation in Iceland (Stykkisholm, Berufjord, and Vestmanno). Southernmost Greenland (Ivigtut), Spitsbergen, and northernmost Europe (Bodo, Karesuando, Haparanda, and Archangel).

In addition to the comparison covering the period 1901-) with ice conditions in the area as a whole, a comparison was also made of conditions prior to 1900 using the data of the ice off Iceland. Although short period fluctuations in the ice in that region frequently differ from those in other sections in the Atlantic-Arctic, when considered for longer periods such as a decade, the ice fluctuations appear similar in the Greenland Sea as in the Barents Sea (Schell, 1952) and we may assume that over longer periods usually also the ice off Iceland reflects the conditions in the area 50°W to 70°E as a whole. In this way the comparison of the ice limit or ice severity with the precipitation could be extended several additional decades, the limiting factor actually being the precipitation record (rather than the ice) which at the most, in the case of Stykkisholm, goes back to 1857.

TABLE II

Average latitude of ice limit of the area 50°W to 70°E and character of ice off Iceland compared with annual precipitation by decade (1881-1940) in Iceland, southernmost Greenland, Spitsbergen, and northernmost Europe.

Decade	Ice		Precipitation			
	off Iceland	50°W-70°E	Iceland	Southernmost Greenland	Spitsbergen	Northernmost Europe
			%	%	%	%
1881-90	Severe	--	94	98	-	87
1891-1900	Moderate	--	95	96	-	100
1901-10	Moderate	71.8°N	100	87	-	96
1911-20	Moderate	71.2°	91	-	88	94
1921-30	Light	72.3°	109	-	112	110
1931-40	Light	72.5°	110	121	-	114
Average (mm) (1881-1940)			1107	1206	324	574

Because of possible local influence on the precipitation, the stations examined were, whenever possible, combined to provide a regional representation. Thus, the three Icelandic stations, Stykkisholm, Berufjord, and Vestmanno, were combined to represent Iceland; the four stations, Bodo (Norway), Karesuando and Haparanda (Sweden), and Archangel (Russia), were combined to represent northernmost Europe. Southernmost Greenland had to be represented by the single station, Ivigtut, whose record was unfortunately too incomplete for the period 1911-30 to be included in the analysis, and Spitsbergen by observations for 1912 to 1929 only.

Table II, giving the character of the ice off Iceland, together with the average latitude of the ice limit in the area 50°W to 70°E and the values of the precipitation in Iceland, northernmost Europe, southernmost Greenland, and Spitsbergen by decade, shows that the two decades (1921-40) with light ice off Iceland, which are also the two decades with the least southerly extent of ice in the area 50°W to 70°E as a whole, had above average precipitation (Iceland, 9%; southernmost Greenland, 21% (1931-40); Spitsbergen, 12% (1921-29); northernmost Europe, 12% (1921-40)) and that the decade 1881-90 with severe ice off Iceland had below average precipitation (Iceland, -6%; southernmost Greenland, -2%; northernmost Europe, -13%). The decade 1911-20 with only moderate ice off Iceland but with the most southerly extent of the ice for the area as a whole, had below average precipitation (Iceland, -9%; Spitsbergen, -12%; northernmost Europe, -6%).

It was previously shown (Schell, WHOI Ref. No. 50-53) that the decade, 1861-70 with severe ice off Iceland, was accompanied by distinctly below average precipitation in Stykkisholm and it can now be said that the only other station in or near the Arctic (Haparanda in northern Sweden), whose record too covers this decade (1861-70), also had below average precipitation; an average annual value of 406 mm as compared with the long-term average of 540 mm (1881-1940), or -25% below the normal.

Thus, the precipitation trend in the Atlantic-Arctic and adjacent land areas would appear to vary with the spread of the ice in the Arctic. A more southerly position of the ice limit, etc., presumably being associated with an expanded Polar anticyclone and a more southerly storm track, is accompanied by less precipitation and, conversely, a more northerly position of the ice limit, etc., presumably connected with a contracted Polar anticyclone and a more northerly storm track, is accompanied by more precipitation.

An analysis of the pressure distribution in the Arctic and adjacent land areas by decade, in relation to the ice limit to

complement the analyses made for the temperature and precipitation, is contemplated for the future.

B. Ice in the Arctic and average pressure in the northern hemisphere.

The apparent relation of the ice limit in the Atlantic-Arctic with the precipitation in southernmost Greenland, Iceland, Spitsbergen, and northernmost Europe noted above, and with the temperature, etc., previously investigated, may be envisaged as a phase of a relationship involving the circulation over a much larger area. Thus, a comparison of the ice limit between 50°W and 70°E with the average pressure or total mass of air over the northern hemisphere (north of 20°N) gave for the twenty-year period, 1901-20, with above average ice conditions, 0.28 mb above the thirty-nine year (1901-39) average of 1015.20 mb as against -0.29 mb for the nineteen year period 1921-39* with below average ice conditions (Table III).

For shorter time intervals and more limited ice areas, the tendency for more ice in the Arctic to be associated with higher pressure in the northern hemisphere (north of 20°N) etc., is less pronounced. Thus, a correlation of the yearly values of the ice in the Greenland Sea only with the northern hemisphere pressure (north of 20°N) based on the forty-one year period, 1899-1939, gave a coefficient of $r = 0.35$ (S.E. = $\pm$ 0.16).

TABLE III

Departure from average pressure in the northern hemisphere (north of 20°N) and mean latitude of ice limit 50°W to 70°E

Period	Pressure mb	Ice Limit °N
1901-20	0.28	71.6
1921-39	-0.29	72.5

The relationship of the Arctic ice with the pressure in the northern hemisphere (north of 20°N), indicated here, suggests that if such a relationship also obtains for the southern hemisphere then the longer period fluctuations of the ice in the Antarctic would either have to be out of phase with those

* For the year 1939, only the first six months' pressures were available.

in the Arctic or an excess of air, for example north of 20°N and south of 20°S, would have to be balanced by a deficiency in between these latitudes.

C. Foreshadowing the severity of the iceberg season off Newfoundland in 1952

Employing the relationship of the iceberg count off Newfoundland with several elements of the preceding North Atlantic circulation (Schell, 1952), an examination was made of the factors in the formula giving the iceberg count south of 48°N during the spring and early summer. The factors are: (1) average December to March pressure difference Belle Isle to Ivigtut taken as a measure of the northwesterly air flow which contributes to the southward drift of the bergs along the Labrador coast, (2) December to March temperature at St. John's, Newfoundland, reflecting both the frequency and strength of the northwesterly winds and the coldness of the air to which the icebergs are exposed and (3) December to March temperatures at Bermuda and Upsala when taken in conjunction with the temperature at St. John's, assumed indirectly to reflect the intensity of the general air circulation over the North Atlantic (Schell, ibid.).

The average December 1951 to March 1952 values of the above four factors expressed as departures from their respective long-term averages are:

Pressure Difference	Temperatures		
Belle Isle to Ivigtut mb	St. John's °F.	Bermuda °F.	Upsala °C.
$\Delta = 0.5$	4.2	0.5	1.2

Introducing the above departures in the formula, the value of the departure from the average in the iceberg count is -0.9, the long-term average being 4.8 on the non-linear scale of 10 and indicating that the iceberg count in 1952 will be below the average.

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DEVELOPMENT OF INSTRUMENTS

Unattended Instruments. Five of the 400-day temperature recorders were built during the quarter and will soon be tested in local waters. It is planned that they will be suspended below U. S. Coast Guard buoys in Nantucket Sound. Further efforts during the quarter were directed entirely toward the development of equipment and techniques for the recovery of unattended instruments in deep ocean water after long periods of time. Aside from the most preliminary thought, no work has been done on the instruments themselves. The design requirements adopted for the program assume that an instrument must be recovered from any depth up to 3,000 fathoms after a period of time ranging up to 400 days with a minimum expenditure of ship's time, either in the planting or recovery operation.

The system decided upon involves a buoy which will produce a sound audible to shipboard hydrophones, suitable instrumentation aboard ship to locate the buoy within fairly close limits, and an anchor release mechanism activated sonically, possibly by the explosion of a small charge lowered from the ship. Six components of the system have received consideration

1. The sonic buoy. Detailed design studies show that a battery-powered device can be made which will activate a hammer with one foot-pound of energy per stroke once per minute for 150 days, the mechanism, exclusive of the case, to weigh less than 80 pounds. Construction of a preliminary mechanism, for test in several buoy configurations, will start upon receipt of components.

2. Locating gear. Shipboard instrumentation has been planned in block diagram form. Basically, it consists of hydrophones, associated amplifiers, and an analog computer

whose input comes from the amplifier, and whose output is presented on two dials, giving the direction to the buoy in azimuth and elevation. The design features involve standard integrating and selector circuits, possibly gyro-actuated pitch and roll correction, and output servos. Final design of this device is being deferred until components have been proved, but no difficult problems are anticipated.

3. Flotation elements. Some flotation external to the sonic buoy is anticipated, because of varying buoyancy requirements of the instruments themselves, and with the sounder at extreme depth the flotation elements must withstand the pressure at that depth. The most promising method appears to involve glass spheres: these are being investigated and will be tested. Other possibilities which are being considered are a safe, cheap organic substance of low density as a substitute for gasoline; and a gas generator which will supply the buoyancy at ambient pressure, possibly involving an acid-metal reaction or a pyrotechnic material.

4. Cable. For instruments floating near the surface, a length of cable approximately the depth of the water is required. For this application, in which the principal load is the weight of the cable itself, nylon or fiberglass compare favorably with steel, primarily because of their greater buoyancy in sea water. While the use of steel cable is planned in the early test phase, the other materials are receiving consideration.

5. Anchor. Initial testing will be done using a dead weight type anchor, with a short scope; i.e., no cable lying on the bottom. If this proves unsatisfactory in relatively high velocity currents, an anchor adapted from a momentum type coring tube is planned.

6. Release gear. A sonically operated device to release the anchor and allow the instruments to surface is planned, but no design work has been done to date on this component. It is anticipated that it will be actuated either by an explosive charge or by a single frequency sound generated by shipboard gear.

THEORETICAL STUDIES

<u>Inhomogeneous Turbulence</u>. The irregular motion of fluids to which the name turbulence is given is of such complexity that there can be little hope of a theory which will describe

in detail the velocity, temperature and density fields at every instant. Existing theories are either statistical or empirical.

The empirical theories seek to determine the gross aspects of the turbulent motion by making assumptions relating the shearing stresses to the equations of motion of the mean flow. The various "mixing length" theories are of this sort and their final assumptions necessitate one or more empirical constant.

The statistical theories deal with the spectrum of the fluctuating fluid fields but have not yet successfully treated the situations in which the properties of the field vary with position.

Dr. Malkus seeks to deduce the spectral structure of the inhomogeneous turbulent field, hence linking the topical areas of the empirical and statistical efforts. The tools of this investigation are certain statistical mechanical principles applicable to steady state irreversible fluid dynamics and the constraints imposed on the fluid motion by the hydrodynamic equations and the boundaries. The first theoretical conclusions, concerned with the heat transport and spectrum of thermal turbulence between horizontal conducting surfaces, have been tested in laboratory experiments to large Rayleigh numbers. These results are also applicable to the turbulent shearing stress between rotating cylinders up to Reynolds numbers of two thousand. Indeed, the data gathered by G. I. Taylor in such experiments is predicted by the theory.

This work continues with the hope of establishing the detailed character of turbulence in a pipe, for the amassed data concerning such turbulence permits extensive comparison with the theory.

MODEL STUDIES OF OCEANS

During the past quarter a number of runs with the rotating basin showed that at the equilibrium rate of rotation westward intensification of the circulation did not occur. At somewhat higher rates of rotation, however, satisfactory approximations of the ocean circulation were produced, and at lower than equilibrium rates the circulation pattern was reversed 180° so as to produce the most intense currents along the eastern margins of the oceans. This puzzling result was very kindly explained by Dr. C.-G. Rossby, who showed clearly that the change in depth of water between the rim and the pole of the basin contributed a vorticity tendency which could aid, cancel, or overpower that due to the change of latitude in the case of water parcels moving north or south. At the equilibrium rate of rotation the normal

depth of water at the rim of the basin is $1/\sqrt{2}$ less than that at the pole, so that a parcel of water moving from the rim toward the pole undergoes vertical stretching and horizontal convergence which produces a cyclonic vorticity tendency exactly equal and opposite to that due to the change in latitude. Westward intensification is therefore nil under such circumstances. It also follows that when the rim depth is still less than that at the pole eastward intensification should occur, and that westward intensification cannot only be achieved but controlled by varying the ratio of the normal depth at the rim to that at the pole.

MODEL STUDIES OF ESTUARIES

Tidal Flushing. During the past quarter we have run in the laboratory a series of tests simulating conditions in the Arons and Stommel theory of tidal flushing. In the theory the authors introduced the coefficient B, relating the coefficient of eddy viscosity to the tidal excursion times the tidal velocity. The purpose of the experiments was to determine if B varied for different conditions of flow, and to find, if possible, on what it depends.

The result of the theory is to predict only the horizontal distribution of salinity along the estuary. The salinity is treated as a property of the fluid, which is diffused, and no account is taken dynamically of the varying density. It was hoped that this latter factor would have little influence in the experiments. In the flume, however, when fresh and salt water are used for the river and ocean respectively, it has been found extremely difficult to eliminate the tendency of the waters to stratify and form the salt wedge phenomenon. It was therefore necessary to do away with the difference in density of the river and ocean waters; i.e., to use only fresh water or only salt water from both the ocean and river. By coloring the water introduced as the river with a dye, the varying concentration of color would correspond to the varying freshness of the water.

In the experiments, sea water was used for both the ocean and river, and to indicate the freshness, the river water was dyed with fluoroscein. Upon establishing the various operating conditions, as the tidal amplitude and period, and the river discharge, the equipment was allowed to operate at least four hours in order to reach equilibrium. Samples were then taken (by siphon) uniformly over the low tidal depth and continuously over several tidal cycles. A Klett-Summerson Colorimeter was used to determine the color concentration in each sample.

For the 31 tests made so far, the coefficient B has not proven constant. There appears to be some definite dependence of B on the mean river velocity divided by the ratio of the tidal amplitude and the tidal period.

We are planning to make further tests, extending, if possible, the range of flushing numbers presently covered, and to investigate the influence of various intensities of turbulence resulting from roughness in the form of fine wooden lattices.

MISCELLANEOUS

Salinity Titrations. The following groups of salinity samples have been titrated:

ALBATROSS III, Cruise #41	400
HAZEL III, Cruise #8	250
STIRNI, Cruise 1	300
Great South Bay, New York	80
STIRNI, Cruise #3	250
HAZEL III, Cruise #10	250
Miscellaneous	50
Total	1,580

Two U. S. Coast Guardsmen, members of Mr. Soule's group of the International Ice Patrol, were trained for a period of two weeks each. Mrs. Alice B. Holmes was trained for one week in preparation for Project SKI-JUMP II.

The Constant Temperature Room was cleaned and painted. During the painting the following work was accomplished:

1. 4 German Richter & Wiese Knudsen burettes were calibrated by standard methods.

2. 3 Macalaster Bicknell Knudsen pipettes were calibrated.

3. For ALBATROSS III the following:
   All densities were calculated
   Salinity-Depth graphs
   Density-Depth graphs

This work has been performed by two full-time technicians under the supervision of Mr. Bumpus.

<u>Thermometer Calibrations.</u> During the first quarter of 1952, some 55 reversing thermometers were calibrated and/or tested for the Cuban Hydrographic Office, the U. S. Coast Guard, and this Institution. Of these, four were malfunctional, and very little work was done on them.

Total tests were: 61 ice points (some 300 observations); 54 V_0 determinations (some 270 observations); 10 pressure factor determinations (some 100 observations and calculations); and about 500 tests at other points on the temperature scale (some 2,500 observations).

Two new Richter & Wiese unprotected reversing thermometers were received from Germany for this Institution, and two new Watanabe protected reversing thermometers (post-war manufacture) were sent to this Institution from Japan for evaluation. These have been calibrated and are now awaiting assignment to a ship for further test.

In February, the U. S. Coast Guard received some of the first production models of new reversing thermometers made by the Taylor Instrument Cos. of Rochester, New York. These instruments were given extensive tests by this Institution, the results of which have been submitted to the U. S. Coast Guard in a special report.

This Institution has received from the U. S. Navy Hydrographic Office three reversing thermometers to replace the three W.H.O.I. instruments lost on Hydrographic Office ships in 1951.

Two papers were prepared by Mr. Whitney, one "Notes on Malfunctional Behavior and its Correction in Deep Sea Reversing Thermometers" and the other "Comments on the Determination of the Pressure Factor, "Q", of Unprotected Reversing Thermometers". It is expected that these will be issued as technical reports during the second quarter.

As of 1 April, pending delivery of certain new reversing thermometers still on order, all work on hand has been completed and all records up to date.

This work has been carried out by Mr. G. G. Whitney, Jr., under the supervision of Mr. Bumpus.

BIBLIOGRAPHY

<u>Papers Submitted for Publication.</u> The following papers were submitted for publication:

Malkus, W. V. R., and M. E. Stern: Determination of ocean transports and velocities by electromagnetic effects. J. Mar. Res.

Schell, I. I.: On the role of the ice of Iceland in the decadal temperatures of the air in Iceland and some other areas. J. du Cons., 18 (1).

Papers Published. The following papers were published during the quarter:

Schell, I. I.: The problem of the iceberg population in Baffin Bay and Davis Strait and advance estimate of the berg count off Newfoundland. J. Glaciol. 2 (11):58-59.

Seiwell, H. R.: Experimental correlogram correlation analyses of artificial time series (with special reference to analyses of oceanographic data). In: Proc. Second Berkeley Symposium on Mathematical Statistics and Probability, Univ. of Calif. Press: 639-666, 27 text figs. (Published posthumously).

PERSONNEL

The following personnel were engaged in either full or part-time activity under this contract. Not included in this list but contributing to the work were shop-workers, maintenance personnel, crews of vessels, and the administrative staff of the Business Office.

Assignment	Name	Title
DIRECTION AND ADMINISTRATION	Ed. H. Smith	Director
	C. O'D. Iselin	Sr. Physical Oceanographer
	A. C. Redfield	Associate Director
	R. A. Veeder	Assist. to the Director
	Jeanne M. Backus	Secretary
HYDROGRAPHIC OBSERVATIONS AND ANALYSES	Nellie Andersen	Senior Technician
	A. B. Arons	Associate in Physics
	D. F. Bumpus	Oceanographer
	J. Chase	Research Assoc. in Meteorology
	H. G. Farmer	" " " Engineering
	F. C. Fuglister	Oceanographer
	C. R. Hayes	Research Assist. in Oceanograph
	S. F. Hodgson	" " " Engineering
	J. F. Holmes	Res. Assoc. in Oceanography
	C. O'D. Iselin, Jr.	" Assist. in "
	J. M. Kemp	" " " "
	B. H. Ketchum	Marine Microbiologist
	H. A. Kierstead	Physical Chemist
	W. V. R. Malkus	Physicist
	W. G. Metcalf	Res. Assist. in Oceanography
	I. I. Schell	Meteorologist
	W. L. E. Sinkler	Observer
	H. M. Stommel	Oceanographer
	L. A. Thayer	Research Engineer
	Evangeline Tollios	Senior Technician
	W. S. von Arx	Oceanographer
	L. P. Wagner	Res. Assist. in Oceanography
	L. V. Worthington	Res. Assoc. " "
PHOTOGRAPHY, DRAFTING AND TITRATING	F. A. Bailey	Draftsman
	Gloria Gallagher	Multilith Operator
	Marion O'D. Lane	Technical Assistant
	D. M. Owen	Res. Assoc. in Oceanography
	F. C. Ronne	Photographer
	Eva Shelnut	Draftsman
	J. W. Stimpson	Draftsman
	Phyllis Vail	Technical Assistant
	Nancy H. Williams	Technical Assistant
	G. G. Whitney, Jr.	Senior Technician

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